

MAMMALIAN SPECIES

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Napaeozapus insignis. By John O. Whitaker, Jr., and Robert E. Wrigley

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Napaeozapus Preble, 1899

Napaeozapus Preble, 1899:33, proposed as a subgenus of *Zapus*, on 8 August. Type species *Zapus insignis* Miller, 1891: 742, by monotypy.

CONTEXT AND CONTENT. Order Rodentia, Suborder Myomorpha, Superfamily Dipodoidea, Family Zapodidae, Subfamily Zapodinae. One species is included in this genus as treated below.

Napaeozapus insignis (Miller, 1891)

Woodland Jumping Mouse

Zapus insignis Miller, 1891:742. Type locality Restigouche River, New Brunswick, Canada.

Napaeozapus insignis: Miller, 1899:330, 18 November.

CONTEXT AND CONTENT. Context noted in generic summary. The genus was monographed by Preble (1899). Five subspecies are currently recognized (Wrigley, in press), as follows:

- N. i. insignis* (Miller, 1891:742), see above (*algonquinensis* Prince and *gaspensis* Anderson are synonyms).
- N. i. abietorum* (Preble, 1899:36). Type locality Peninsula Harbor, north shore of Lake Superior, Ontario, Canada.
- N. i. roanensis* (Preble, 1899:114). Type locality Roan Mountain, Mitchell Co., North Carolina.
- N. i. frutectanus* Jackson (1919:9). Type locality Crescent Lake, Oneida Co., Wisconsin.
- N. i. saquenayensis* Anderson (1942:40). Type locality Trout Lake, near Moisie Bay, north shore of Gulf of St. Lawrence, Saguenay Co., Quebec, Canada.

DIAGNOSIS. *Napaeozapus* is monotypic and differs from *Zapus* and from *Eozapus* in having 3 rather than 4 molariform teeth. It further differs from *Zapus* in having the tip of the tail white, and from *Eozapus* in lacking a dark longitudinal stripe on the belly.

GENERAL CHARACTERS. A longer description is presented by Wrigley (in press). Females average slightly larger than males in most external and cranial characters. Mouselike in appearance; size medium, total length 204 to 256 mm, tail length 115 to 160 mm, body length 80 to 100 mm, hindfoot length 28 to 34 mm, ear length 15 to 18 mm, weight 17 to 26 g (without embryos or fat); tail long (59 to 63% of total length); hind feet elongated for saltation; front feet small; 4 pairs of teats—1 pectoral, 2 abdominal, and 1 inguinal; mystacial vibrissae conspicuous; pelage coarse due to stiff guard hairs; pelage of dorsal stripe brown to black, on sides orange with yellow or red tint and with scattered dark guard hairs, underparts white; tail distinctly bicolored, grayish brown above, white below, virtually always with a white tip (to 42 mm). Skull murine in appearance (Figure 1); zygoma with jugal plates extending dorsally along maxillary ramus and articulating with lacrymal; infraorbital foramen large and oval; nasals projecting considerably beyond the incisors; incisors colored orange or yellow, upper incisors grooved; premolars absent; molars rooted, semi-hypsodont, flat-crowned with complicated pattern of re-entrant folds and islands (Figure 2); dentition i 1/1, c 0/0, p 0/0, m 3/3, total 16.

The species exhibits marked clinal variation in numerous characters, with the northern populations averaging 12% (7 to 17) larger than those in the southwestern part of the range. Southern populations are characterized by reddish orange pelage, becoming more yellowish northward and eastward. In the northwest, populations display pale side coloration, dark dorsum and white ear edging.

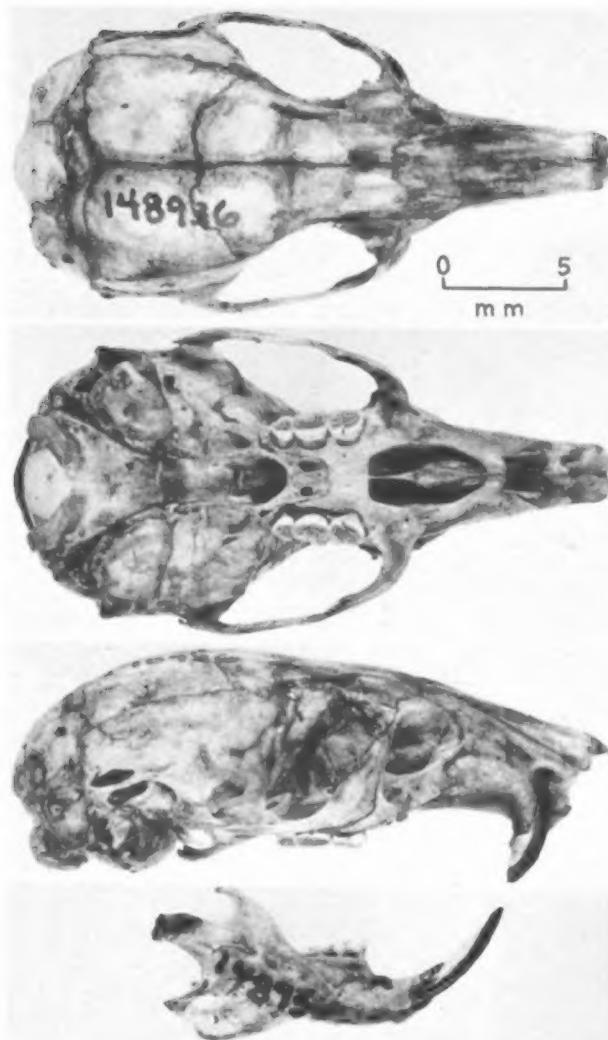


FIGURE 1. Skull (from top to bottom) in dorsal, ventral, and lateral views, and dentary in lateral view, of AMNH no. 148936 from Mt. Katahdin, Maine. Photographed in ultraviolet light by Mr. R. E. Logan, Department of Photography, The American Museum of Natural History.

DISTRIBUTION. *Napaeozapus* occurs throughout the northeastern United States and southeastern Canada (Figure 3). Elevation range is from near sea level north of the St. Lawrence region to 3000 to 6600 ft (900–2000 m) in the Appalachian Highlands. In the southern part of the range, many populations are isolated on mountain peaks and in cool moist coves (for example in the Roan and Smoky mountains and others of Tennessee and North Carolina) or in relict stands of forest (northeastern Ohio, western West Virginia) as a result of the post-glacial movement of the range northward. A record from west-central Indiana is probably in error (Whitaker and Mumford, 1971).

FOSSIL RECORD. The earliest known *Napaeozapus* is from the mid-Pleistocene deposits at Cumberland Cave, Maryland, at the periphery of the present range. The lower jaw, molars, and incisors are proportional in size to *N. insignis*

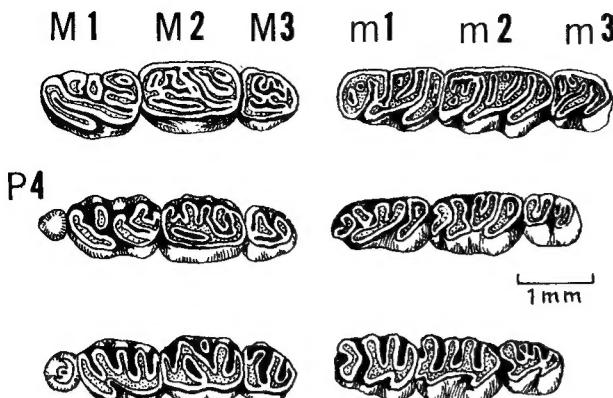


FIGURE 2. Upper and lower molariform dentitions of three genera of zapodids in occlusal views (from Krutzsch, 1954: 360). Premolars and molars are identified by initials and numbers. Upper dentitions are at the left. Upper row is *Napaeozapus*, middle row *Zapus*, and lower row *Eozapus*. Note the increasing complexity of teeth from bottom to top, and the loss of the P4 in *Napaeozapus*.

(Gidley and Gazin, 1938). *Napaeozapus* remains also have been found at four late-Pleistocene sites, two of which are on the southeastern periphery of the range—New Paris no. 4, Bedford Co., Pennsylvania (Guilday, et al., 1964), and Natural Chimneys, Augusta Co., Virginia (Guilday, 1962); and two localities considerably outside the present distribution—Bootlegger Sink, York Co., Pennsylvania (Guilday, et al., 1966), and Robinson Cave in north-central Tennessee (McCrady and Schmidt, 1963; Guilday, et al., 1969). Specimens from New Paris no. 4 and Natural Chimneys average 10% larger than those now inhabiting the same areas, but closely approximate the large northern races.

FORM. The pelage (Wrigley, in press) of *Napaeozapus* consists of underfur and guard hairs. The underfur is fine, wavy, and 2 to 6 mm long. The guard hairs are coarse or fine (overhairs), and are stiff, tapered at both ends, and elliptical in cross section. The coarse guard hairs are 9 to 11 mm long, and the overhairs are 5 to 10 mm long. The color and banding patterns of hairs vary with the area of the pelage. The vertebral column has 7 unfused cervical vertebrae; 12 thoracics; 7 large lumbars, the posterior 4 having pronounced neural and

transverse processes; 4 sacrals with transverse processes fused; and 39 caudals, with small H-shaped sesamoid bones between the larger caudals. The tail has been elongated by an increase in both number and length of vertebrae. The 5 metatarsals are enlarged (first and fifth subequal) but not fused. The tibia and fibula are fused proximally, the fibula is reduced distally. Five digits are present on the front and hind limbs, though the pollex is reduced. In a study of the ear ossicles, Krutzsch (1954) found features of the malleus and incus that differentiated *Napaeozapus*, *Zapus*, and *Eozapus*. The shape of the ceratohyal and thyrohyal elements of the hyoid apparatus differs in *Napaeozapus* and *Zapus* (Wrigley, in press). The cheek-teeth (see Figure 2) of the Recent zapodids, *Eozapus*, *Zapus*, and *Napaeozapus*—in that order—show a progressive decrease in size and final loss of P4, increasing complexity of occlusal surface, and several other characters (Krutzsch, 1954). Dental abnormalities in *Napaeozapus* were summarized by Wrigley (in press). Klingener (1964) presented a comparative myology of *Napaeozapus*, *Zapus*, and related taxa, and reported no constant differences between the two jumping mice. The carotid arterial system of *Napaeozapus* is basically the same as in *Microtus* (Guthrie, 1963). The os penis structure and its position within the phallus are illustrated by Wrigley (in press). The os penis (Krutzsch, 1954), the os clitoris (Whitaker, 1966), and the glans penis (Wrigley, in press) serve to differentiate the Recent zapodids. The os penis varies in size geographically, being larger in the northern races—average length 6.3 mm, width of base 1.0 mm, height at base 0.9 mm. The os clitoris in four specimens ranged from 2.1 to 2.4 mm in total length and from 0.17 to 0.24 mm in greatest width. The distal end of the glans penis is covered with numerous rows of epidermal spines, enlarged proximally as large scales tipped with spines. The glans is larger and more rectangular in *Napaeozapus* than in *Zapus*. The male accessory reproductive glands consist of bulbo-urethral, vesicular, and 3 pairs of prostate glands, however ampullary and preputial glands have not been located (Wrigley, in press). Sudoriferous glands are lacking in zapodids although present in nearly all microtines and new world cricetines. Sebaceous glands are extremely large in zapodids, practically filling the subcutaneous area of the lower lip, and extending posteriorly over the ventral margin of the cheek (Quay, 1965).

FUNCTION. Relatively little physiological work has been done on this species, and much that has relates to hibernation. Brower and Cade (1966), working with 10 woodland jumping mice (average weight of 20.9 g), found an average *ad libitum* water consumption of 160 mm³/d/g of body weight. The deep body temperature of *N. insignis* remained at 37°C at ambient temperatures ranging from 5° to 33.5°C, but increased when tested at 37°C (ambient). The average minimum metabolism for 11 mice (at ambient temperature of 31°C and average weight of 21.6 g) used oxygen at 1800 mm³/hr/g of body weight, and produced carbon dioxide at 1300 mm³/hr/g. Pearson (1947) measured the basal metabolic use of oxygen at 2400 mm³/hr/g. Body heat was lost about 17% more rapidly (in the range of 20° to 30° C) by jumping mice than by *Peromyscus maniculatus* (Brower and Cade, 1966). Evaporative water loss was 3.2 mg/hr/g body weight in seven *Napaeozapus* at 29°C (average weight of 20.8 g), and this loss was 4.2 in 13 mice at 25°C (average weight of 24.9 g). Brower and Cade hypothesized that this low evaporative water loss in a form of the moist forests was an adaptation for hibernation rather than for the active phase of the animal's life. Neumann and Cade (1964) divided 10 jumping mice (8 *Napaeozapus* and 2 *Zapus hudsonius*) into two groups of five, with one group on long days (16 hr of light, 8 of dark) and the other on short days (16 hr of dark, 8 of light), in an effort to determine effects of photoperiod upon hibernation. Mice were housed individually in a refrigerator in which the ambient temperature was held at 2° to 5°C. The mice on short days fattened before hibernation, and hibernated for longer periods of time (mean of 9.4 days), than did their long-day counterparts (mean of 3.3 days). The long-day mice remained awake for average periods of 2.9 days between periods of hibernation, as compared to 1.5 days in the short-day mice. Short-day mice averaged 27.8 g at the beginning of the experiment, increased to 30.0 g in the 2 weeks just prior to hibernation, decreased rapidly just after the mice entered hibernation, then leveled off. In the long-day mice, the average weight was 27.4 g initially and decreased to 25.8 g in the 2 weeks just before hibernation, then continued to decrease rapidly and continually throughout their sporadic periods of hibernation, until death occurred.

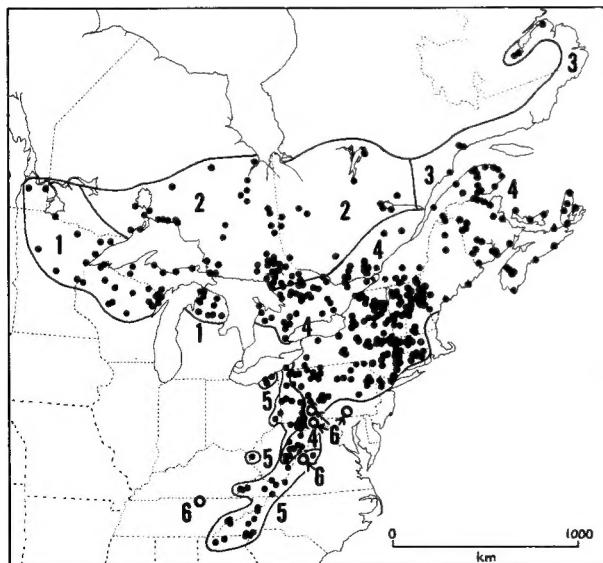


FIGURE 3. Range of *Napaeozapus insignis* in eastern North America. Known Recent localities are shown by dots for the following subspecies: 1, *N. i. fructecanus*; 2, *N. i. abietorum*; 3, *N. i. saguenayensis*; 4, *N. i. insignis*; and 5, *N. i. roanensis*. Fossil locations are shown by circles labelled 6. Estimated ranges of the subspecies are outlined.

ONTOGENY AND REPRODUCTION. Sheldon (1934) kept a *Napaeozapus* alone in a cage for 29 d (days) before it gave birth, hence, in this case gestation was 29 d or longer. This seems long since the gestation of *Zapus hudsonius* is about 18 d, prolonged 2 to 3 d if the animal is lactating when mated (Quimby, 1951). Sheldon (1938) stated that one female gave birth 23 d after being caged with males and that another produced a litter 25 d after being caught, hence these values can be considered as maximum and minimum gestations in these respective cases. Schwentker (1957) reported that there was no postpartum estrus in *Napaeozapus*, though it appeared possible to induce estrus by weaning the young. In contrast, Quimby (1951) found that *Zapus* could mate successfully soon after parturition while nursing continued. We have summarized reproductive information on 170 females from the central part of the range, drawing from personal work, the literature, and museum specimens. The earliest records of pregnancy are 8 and 9 May (Gifford and Whitebread, 1951) although few females carry young in May. Most females are pregnant or show signs of recent parturition in June, and those not breeding appear mainly to be individuals from late litters of the previous year. Reproduction continues at a low rate through July, mostly by females producing their first litter of the season. A second breeding peak is apparent in August, with many females delivering a second litter. The latest recorded pregnancy was 1 September (Connor, 1960). Males and females are not sexually active until their second season. Eighty litters averaged 4.6 (2 to 7) embryos and 45 counts of placental scars averaged 4.3 (2 to 7). The number of young in second litters is reduced, and two annual litters are more often produced in southern populations than in the north.

Layne and Hamilton (1954) recorded the development of young individuals of *Napaeozapus* from birth. The newborn young were unpigmented and hairless, and had rugose, loose, pinkish skin. The four pairs of mammae were visible in both sexes as light spots. Facial vibrissae were present, and the pinna of the ear was sealed and tightly folded. The eye was visible as a dark ring about 1.5 mm in diameter. Blunt claws appeared as tubercles on all digits of forefeet and hind feet. Standard measurements (total, tail, and hind foot lengths) of the newborn young were 35.2, 11.0, and 5.0, and the weight was 0.87 g. Sheldon (1934) presented standard measurements of two individuals one day old as 41 and 44 mm; 11 and 13 mm; and 4.5 and 6 mm. Measurements of a third individual found dead a few hours after birth were 39, 9.5, and 5 mm. In the young studied by Layne and Hamilton there was little change by the end of the first week, although the mystacial vibrissae were now about 2 mm long and the pinna was more prominent. By day 10 after birth, minute pigment spots were visible beneath the surface of the skin on the head, body, and tail, and the ear pinna had unfolded. The external auditory meatus was still closed. The eyes bulged slightly and a faint crease had appeared where the eyelids eventually separated. By day 12 the dorsal body regions were noticeably grayer and the tip of the tail was flesh colored. Fine hairs were visible in the dorsal regions and on the limbs. The posterior mystacial bristles were now about 6 mm long and the plantar tubercles of the hind feet had become black. By day 14, the body, including the belly, was covered with fine hair, and the skull sutures and viscera were no longer visible through the skin. By day 19, the claws were well formed, and the lower incisors protruded through the gums about 0.2 to 0.3 mm. By day 21, the middorsal dark band, which earlier had been distinct but then disappeared, had become distinct permanently. The lower incisors were about 0.5 mm long and the upper incisors were just evident. By day 24, the young were well furred, the mammae were still evident through the hair, the upper incisors were about 1.0 mm long, and the lowers were about 0.5 mm. The eyes opened by day 26, as did the external auditory meatus. The lower incisors were now about 2 mm long and the upper about 1 mm. On day 31, the mammae were no longer visible, the incisors had become yellow, and the grooves of the upper incisors were prominent. By day 34, the young had the appearance of adults, except for size and the color of the sides, which appeared yellowish brown as in *Zapus* rather than orange-brown, as is characteristic for adult *Napaeozapus*. There was a molt to adult pelage between days 63 and 80. Some average weights and measurements at various ages are given (Table 1). Sheldon (1938) reported on two young of 47 days of age that weighed 27 and 25 g.

TABLE 1. Representative weights and measurements of young *Napaeozapus insignis* (from Layne and Hamilton, 1954).

Days	Total length	Tail	Hind foot	Weight
6	48.0 mm	16.0 mm	6.5 mm	1.6 gm
14	73.0	25.0	12.0	3.9
21	112.0	46.0	19.5	6.7
26	123.0	70.0	23.0	8.5
40				10.6
62				14.1
64	199.0	120.0	28.0	
81				17.4
136				22.8

Wrigley (in press) studied the molt sequence in 270 specimens. No subadult molt was found. Young from spring litters exhibited new hair in late August and September (at 2 months of age) while those from summer litters molted in late September and October, or the following spring. Adults molted once a year, from mid-June to early September (mostly in August). New hair first appeared on the cheeks and sides of the neck, then spread to the rostrum, shoulders, and forelimbs. The molt progressed posteriorly along the sides, spreading later to the back and belly, and lastly to the rump and hind limbs.

ECOLOGY. *Napaeozapus* inhabits the spruce-fir and hemlock-hardwood forests in the eastern half of North America. Its range coincides well with the combined ranges of balsam fir (except in the forest-tundra ecotone of the boreal forest) and eastern hemlock. Data on habitat from every province and state in which the species occurs are summarized by Wrigley (in press). *Napaeozapus* selects cool, moist environments within the forest or forest-edge. However, the overall distribution seems to be restricted more by the availability of suitable vegetation than by direct physiological stress of low moisture, temperature extremes, or short growing season in the north. Brower and Cade (1966) found no restriction to particular kinds of woody vegetation. *Napaeozapus* inhabits bogs (Morris, 1948) and *Sphagnum* swamps (Sheldon, 1936). It has been reported as a resident of wet areas (Preble, 1956) and of dry areas (Sheldon, 1934). Whitaker (1963) presented information on relative numbers of *Napaeozapus* taken in various habitats. Swamps, mesic woods, and wet woods were most often inhabited in New York; damp rocky areas also were favorable. Preble (1956) stated that greatest populations are found within grass, sedge, and alder bordering small streams, and in moist areas of sedges and grasses in the forest. Brower and Cade (1966), Whitaker (1963), and Connor (1960) all found that there was no special association with habitats near water, but Whitaker (1963), Snyder (1924), and Brower and Cade (1966) found a strong association with ground cover. Brower and Cade indicated that this cover was often in the form of low woody vegetation, whereas Whitaker (1963) found that herbaceous vegetation was preferred.

Zapus and *Napaeozapus* are fairly well segregated ecologically in different stages in the successional sequence of plant communities, with *Zapus* primarily in meadows and *Napaeozapus* primarily in woods. Only in the intermediate stages are the two species commonly found together, particularly in shrub or forest-edge situations. Hamilton (1935), Preble (1956), and others found *Zapus* invading *Napaeozapus* habitats, but not the reverse. Whitaker (1963) concluded that the two species had little or no direct effect on the distribution of each other. Brower and Cade (1966) and Wrigley (in press) concurred, except in forest-edge situations where the abundance of one species may adversely affect the other. Brower and Cade (1966), Wrigley (in press), and the trapping results of other studies show a complementary pattern of local distribution between *Napaeozapus* and *Clethrionomys gapperi*, which may result from the aggressive behavior of the voles. Considering habitat utilization, *Peromyscus maniculatus* seems most likely to compete with *Napaeozapus*; however there is no evidence that either species adversely affects the other. Sheldon (1934, 1938) described *Napaeozapus* as colonial, but Preble (1956) thought that local aggregations were due to isolation of suitable habitats. Wrigley (in press) studied population structure by examining 2100 museum specimens; between 15 May and 15 September, 55% were males. Juveniles (less than 7 weeks old) first appear above ground in late June and reach a peak of 17% of the population in early August. A second but lower peak of juveniles in early September results from the

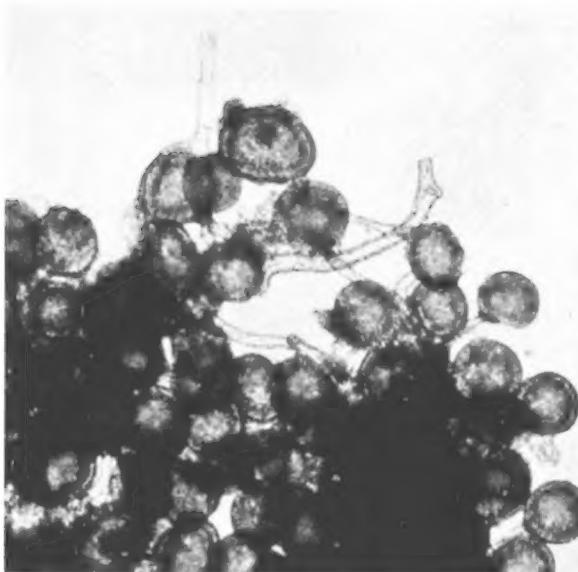


FIGURE 4. Photograph of the fungus *Endogone* as seen in stomachs of *Napaeozapus*. Chlamydospores range from 0.03 to 0.30 mm diameter.

offspring of summer litters. Subadults (7 to 10 weeks old) increase in late July from a low level and comprise 25% of the population during August and September. In September, before the older adults become dormant, animals born that season form almost 70% of the population. Approximately 10% of the sample exhibited attrition of the molars down to or near the cingulum. Inasmuch as wear is likely only during the annual nonhibernating period of 5 to 6 months, some individuals may well be 3 or 4 years old. Townsend (1935) found that *Napaeozapus* comprised 8 to 21% of the small mammal community in central New York. Blair (1941) and Manville (1949) estimated 2.7 and 0.26 woodland jumping mice per acre (6.7 and 0.64 per hectare), respectively, in Michigan, and Brower and Cade (1966) reported 5.2 jumping mice per acre (12.8 per hectare) at Whiteface Mountain, New York. Townsend (1935) gave values of 2 to 24 per acre (4.9 to 59 per hectare). Highest capture success in the study by Whitaker (1963) was 0.21 per 100 trap-nights. High densities also have been reported by Hamilton (1935), Connor (1960), and Preble (1956). Females have a home range of from 1.0 to 6.5 acres (0.4 to 2.6 hectares) and males, 1.0 to 9.0 acres (0.4 to 3.6 hectares) according to Blair (1941). One male was known to travel 117 yards (107 m) in 24 hours (Sheldon, 1938).

Connor (1966) examined the stomachs of 47 individuals and found 77.4% of the contents to be seeds and other plant



FIGURE 5. *Napaeozapus insignis*, from South Bolton, Quebec. Photo by R. E. Wrigley.

materials, and 22.2% insects. *Endogone* and other fungi, larval Lepidoptera, adult Coleoptera, larval Diptera, blueberries, raspberries, small seeds and nuts, mitrewort (*Mitella diphylla*), may apple (*Podophyllum peltatum*), fronds of *Asplenium*, leaves and other green vegetation, grubs and enchytrid worms, and parts of a cranefly, centipedes, and various other small invertebrates were found in stomachs examined by Hamilton (1935, 1941). Connor (1960) reported that seeds, roots, and basal parts of plants comprised 70% of the food in 14 stomachs, and animal material, including lepidopterous larvae, comprised 30%. Saunders (1921) believed that *Napaeozapus* had eaten alder fruits. Whitaker (1963) examined 103 stomachs from Ithaca, New York, 24 from Slide Mountain, Ulster Co., New York, and 18 from North Carolina, Tennessee, and New Hampshire. The most abundant food in all three samples was the subterranean fungus, *Endogone*. It comprised 33.3, 27.6, and 33.5%, respectively, by volume. This fungus is widely used by small mammals as food (Whitaker, 1962; Williams and Finney, 1964). To the uninitiated, this food may appear as a clump of dirt in the stomach, with the individual chlamydospores becoming clear at 25 to 30 power or more (Figure 4). Seeds, collectively, formed 24.2% of the total volume of food in the Ithaca sample, and fruits comprised 11.2%. Lepidopterous larvae and seeds of *Impatiens* were important, forming 10.3 and 6.0%, respectively, of the volume of food in the sample.

Several internal parasites have been found in *Napaeozapus*. The protozoan genus *Hexamita* was found in the only two cecal smears examined (Whitaker, 1963). Freeman (1960, 1959) found the cestode *Hymenolepis bennetti* Freeman and the larval cestode *Cladotaenia globifera* Batsch in woodland jumping mice from Ontario, and Whitaker (1963) found *Hymenolepis* sp. in specimens from New York. The nematode, *Citellinoides zapodis* Dikmans has been found by Dikmans (1939) and Whitaker (1963), and the latter author also found *Rictularia* sp., whereas Lichtenfels (1970) reported *Pterygodermatites* (= *Rictularia*) *parkeri* Lichtenfels. Freeman and Wright (1960) found *Capillaria hepatica* Bancroft in *Napaeozapus* from Ontario.

The most abundant external parasite appears to be the hypopial stage (nonfeeding, transport) of a mite, *Labidophorus* sp. or *Demacarus hypudaei* (see Whitaker, 1963, and Rupes and Whitaker, 1968; but now described as *D. newyorkensis* by Fain, 1969). These mites are tiny, clinging to individual hairs by means of their posterior clasping organs, and may number from one or a few to hundreds per mouse. *Androlaelaps fahrenholzi* (Berlese) (= *Haemolaelaps glasgowi* Ewing) has been found on the woodland jumping mouse by G. E. Wallace (personal communication), Strandtmann (1949), and Whitaker (1963). Other mites, other than chiggers, that have been reported (Whitaker, 1963) are *Eulaelaps stabularis* Koch, *Haemogamasus ambulans* (Thorell) (= *H. alaskensis* Ewing), *Protomyobia brevisetosa* Jameson, and *Radfordia ewingi* Fox. Chiggers (Trombiculidae) reported are *Euschongastia diversa acuta* Farrell by G. E. Wallace (personal communication) and Farrell (1956), *E. setosa* (Ewing) by Farrell (1956), *Neotrombicula harperi* (Ewing) by Brennan and Wharton (1950) and Harper (1929), and *N. richmondi* Brennan and Wharton (1950). The tick, *Dermacentor variabilis* (Say), has been reported from *Napaeozapus* from Nova Scotia (Dodds et al., 1969). Fleas reported include: *Megabothris quirini* (Rothschild) by Holland (1949), Benton and Krug (1956), Jordan (1929), and Geary (1959); *Peromyscopsylla catatina* (Jordan) by Holland (1949); *Ctenophthalmus pseudagyrtis* (Baker) by Hamilton (1935); *Ctenophthalmus* sp. and *Epitedia* sp. by Linzey and Linzey (1968), G. H. Holland (personal communication), Holland and Benton (1968), and Benton and Krug (1956); and *Orchopeas leucopus* Baker by Whitaker (1963). Snyder (1924) found a nest of young *Napaeozapus* that was "infested with fleas." Botflies, *Cuterebra* sp., were reported by Blair (1941), Siegmund (1964), and Abbott and Parsons (1961); Sheldon (1934, 1938) reported *Cuterebra fontinella* Clark from *Napaeozapus* from Vermont and Nova Scotia.

Known cases of predation on *Napaeozapus* are by *Mephitis mephitis* (Hamilton, 1935), *Mustela* sp. (Blair, 1941), *Mustela vison* (Platt, 1964), *Lynx rufus*, *Otus asio*, and *Crotalus horridus* (Linzey and Linzey, 1968), *Aglastromon contortrix* and *Crotalus horridus* (Greenfield, 1938), and *Felis catus* (Wrigley, in press).

BEHAVIOR. Sheldon (1938) and Layne and Hamilton (1954) found that the young squeak continuously after birth, and that they are soon active, moving their hind quarters in

rhythrical writhing motions. At a week of age, they are capable of sharp squeaks when disturbed, and they utter faint sucking sounds continuously. By day 12 after birth, they stand on all four feet, though shakily, and are able to take a few steps before falling on their sides. By day 19, they yawn, stretch, sit up to "wash," and attempt leaps of an inch or so, but they usually land on their sides kicking. By day 26, when the eyes open, they are active and no longer make sucking sounds. They move by slow hops, with the large hind feet pointing outward at about a 45° angle. At day 28, the young are able to jump about a foot, and one individual at this age exhibited the tail drumming seen in adults. At day 34, the young appear as adults except for size. Weaning occurs at this time; the young were seen to eat solid food. The young occupied different parts of the cage from the adult. At day 38, the young attempted to copulate with each other and with the adult. *Napaeozapus* progresses by a quadrupedal walk when moving slowly and a quadrupedal hop for a greater speed. Six feet (1.8 m) is about the maximum distance attained in one jump (Hamilton, 1935; Sheldon, 1934; Wrigley, in press) and jumps of 2 or 3 ft (0.6 or 0.9 m) in length and 1 or 2 ft (0.3 or 0.6 m) in height are more common when retreating (Sheldon, 1938; Wrigley, in press). The animal takes several moderate leaps, stops abruptly under the nearest cover, and remains motionless unless pursued (Sheldon, 1934, 1938; Hamilton, 1935). Although the species climbs well in bushes (Sheldon, 1934; Hamilton, 1935) it does not ascend trees. Hamilton (1935) observed *Napaeozapus* swimming on the surface and Priddy (1949) observed a jumping mouse (likely *Napaeozapus*) swimming underwater. However, Wrigley (in press) found it to have poor endurance (exhaustion in 3 minutes) compared to other rodents. When swimming underwater, only the hind feet are utilized and in unison. On the surface the animal utilizes all four limbs in a strenuous rocking motion, resembling the quadrupedal hop.

Napaeozapus is mainly nocturnal but may be active in late morning and early evening (Sheldon, 1934), particularly if the weather is rainy or cloudy (Bider, 1968). Hamilton (1935), Bider (1968), and Thibault (1969) found increased activity on rainy or cloudy nights; Brower and Cade (1966) and Wrigley (in press) noted no effect, and Sheldon (1934) reported an inverse relationship. Activity may be higher during cold nights than warm (Brower and Cade, 1966; Thibault, 1969) and may continue even at 4°C (Hamilton, 1935). Individuals prepare for hibernation by accumulating large reserves of fat (often one-third of body weight). Neumann and Cade (1964) showed that decreased day length stimulated fat deposition. This normally occurs about 2 weeks prior to hibernation. Klein (1957) found that captives were more apt to enter hibernation if food and water were not supplied. Juveniles and subadults usually lack fat until late in season—late September and October (Preble, 1956; Connor, 1960). Some adults show fat deposition by late August (Goodwin, 1924), most do by mid-September (Blair, 1941), and the majority are hibernating by the end of September (Wrigley, in press). Young of the year, particularly from late litters, are active until October. There is no difference between the sexes in time of entrance into dormancy. Late seasonal records are 24 October in New York (Connor, 1960), 29 October in Pennsylvania (Grimm and Roberts, 1950), and 27 November in the Great Smoky Mountains (Linzey and Linzey, 1968). Food in the digestive tract of a hibernating animal results in death (Sheldon, 1934; Hamilton, 1935). Food is not stored in the hibernaculum, consequently individuals without sufficient fat reserves to last for at least 6 months probably perish. Hamilton (1935) illustrated the folded position of the body and appendages during torpor. The majority of males emerge from hibernation in early May, but most females are not abroad until the latter half of May. Early records are 16 April in Quebec (Wrigley, 1969) and late April in Pennsylvania (Roslund, 1951). There do not appear to be age differences in time of emergence.

Sheldon (1934) found that woodland jumping mice eat by squatting on hind legs and tail and using forepaws to hold food and transfer food to the mouth. They dig their own burrows, or use those of other small mammals. The entrance is concealed during the day. The nest is composed of dry leaves and grass, and may be situated in brush piles or underground (Snyder, 1924). When first captured, jumping mice are extremely nervous, often fatally injuring themselves in attempts to escape. Tail drumming is common. If abundant material is supplied in which to hide, individuals become docile within a month and may be handled and handfed.

Sheldon (1934) noted that captive females attack males during the breeding season. At other times, the species is tolerant of its kind. Captive adults may utter a soft clucking sound, squeal if disturbed while sleeping (Sheldon, 1934, 1938), or remain silent (Wrigley, in press).

GENETICS. *Napaeozapus* has a diploid number of 72 chromosomes (at least 15 pairs biarmed and about 40 smaller and acrocentric autosomes), a fundamental number of about 100, and a large X chromosome representing about 13 percent of the combined length of the haploid set. Females within the same population may exhibit one or two large X chromosomes, though both types have the full diploid complement of 72. It is postulated that in females with only one large X chromosome the other X has undergone a deletion, and cannot be distinguished from the autosomes. Examination of meiotic spreads show a small Y chromosome that likewise cannot be distinguished from the numerous small autosomes in mitotic spreads. These characters are also present in *Zapus princeps*, however in meiotic spreads there appear to be a greater number of chiasmata in *Napaeozapus*, and a secondary constriction present in the X chromosome is more pronounced and centrally located in *Napaeozapus* (Wrigley, in press).

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The editor of this account was S. ANDERSON.

JOHN O. WHITAKER, JR., DEPT. OF LIFE SCIENCES, INDIANA STATE UNIVERSITY, TERRE HAUTE, INDIANA 47809, AND ROBERT E. WRIGLEY, MUSEUM OF NATURAL HISTORY, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS 61801 (PRESENT ADDRESS: MANITOBA MUSEUM OF MAN AND NATURE, WINNIPEG, MANITOBA R3B 0N2).